FEP (fluorinated ethylene propylene) as insulation material for SPE (single pair ethernet) cable
No time-limited (or 12-year) derogation request under the PFAS restriction proposal

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Executive summary

Daikin Chemical Europe welcomes the opportunity to submit comments to the REACH restriction proposal on all PFAS. This non-confidential submission presents a comprehensive analysis focusing on the basic properties and practical suitability of comparable materials in relation to insulation material for single pair ethernet (SPE) cables for high-speed data transmission in automotive, large commercial vehicle, agricultural and construction vehicles, which are under ongoing research and development using fluoropolymers such as FEP (fluorinated ethylene propylene, including both solid and foamed).

This document focuses on the comparison between crosslinked polyethylene (XLPE) and FEP as insulation materials for SPE.

The first section discusses the basic material characteristics required for SPE insulation. From the viewpoint of low dielectric constant even at high frequencies, it is known that FEP has low insertion loss (IL) compared with XLPE and other polyolefins, and it is evident that FEP is a superior material for high speed SPE application.

In the second section, it was examined from the viewpoint of cable performance. In vehicle Ethernet data transmission speeds are envisioned to increase to 1 Gbps and beyond. As data rates increase, it becomes increasingly difficult to maintain signal integrity by XLPE. This is especially true for longer reach cables (15 meters and beyond). Without FEP, it would be unlikely to increase communication speed while maintaining signal integrity, which would have an impact on autonomous driving, which is being considered in the industry. Regulatory approvals for Level 3 traffic-jam pilots, where autonomous systems control driving and monitoring in certain conditions, have been granted. The transition to Level 4 highway pilots, characterised by more advanced automation and higher speeds, is expected for the automotive sector by 2024-2025. However, there is a growing concern regarding the adequacy of communication infrastructure, particularly the need for FEP insulated cable, to adequately handle the information reliability demands of autonomous driving. This concern extends to applications in large commercial vehicles, agriculture, and construction, where autonomous technology promises improved safety and

working conditions. The potential limitation in information capacity of inadequate cable performance could hamper effectiveness in these areas.

The third section underscores the vital role of FEP in meeting SPE standards. FEP-based polymers have displayed superior electrical performance compared to existing materials, with third-party testing confirming their ability to sustain long distances at frequencies of up to 600MHz. Furthermore, testing at speeds exceeding 5GHz, in anticipation of evolving data rate standards, revealed FEP's impressive performance with a 3dB signal strength advantage, indicating its potential for two times higher data speeds. Moreover, data cables with two-times higher capacity use one-half of the power to transmit the same amount of data, thus saving energy.

Industry standards, such as the SAE 1 Gbps standard and the forthcoming ISO 1 Gbps standard, emphasise the need for advanced communication materials. FEP stands as a frontrunner to meet these standards. However, without FEP, concerns arise about the possibility to identify suitable materials that align with the evolving multi-Gbps standards set by SAE and ISO. Including FEP is pivotal to ensure the continued progress and success of autonomous driving technology.

In conclusion, based on the characteristics and future prospects of SPE insulation materials, this submission indicates that FEP is a requisite material, and that other non-PFAS materials such as XLPE may interfere with development. FEP’s superior performance over existing polymers will be critical to meet the ever-increasing data rate demands for transportation applications. Therefore, it is considered appropriate to exempt FEP for SPE application. Also, a period of 12 years is desired as a derogation period under the review clause to examine the possibility of substituting FEP with non-PFAS materials.

Introduction

As vehicle manufacturers strive to keep up with rapidly changing regulations and customer demands for safer, greener, and more productive vehicles, they are realising that CAN bus networks simply cannot support the increased data connectivity required for advanced functionality.

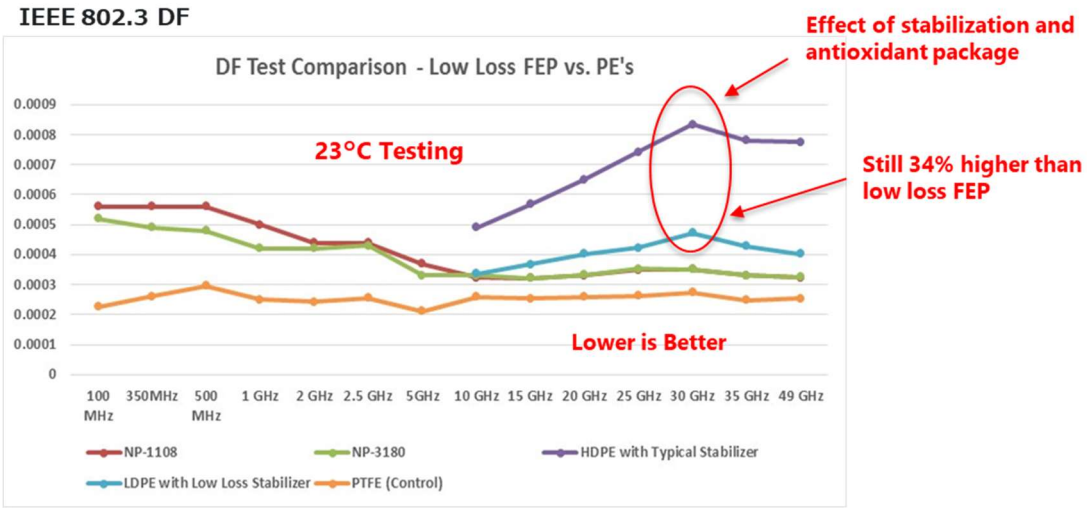
Single-pair Ethernet protocol with speeds of 100 Mbps (100BASE-T1) or faster 1 Gbps (1000BASE-T1) is becoming more important for vehicle designers as advanced functionality demands and data needs continue to increase.

The automotive industry has been incorporating Ethernet in passenger vehicles. Heavy-duty vehicle designers will now use Ethernet from both the automotive industry and those developed specifically to withstand the harsh environments of industrial and commercial job sites such as in construction, mining, and agriculture. Commercial vehicle applications require high performance under high temperatures.

1 Comparison of basic properties of SPE insulation materials

As a wire insulation material, FEP from Daikin (NP-1108, NP-3180) is superior to the best data grade polyethylene, such as HDPE and LDPE, as shown in Fig. 1. The addition of stabilisers (UV, Cu, Fluids) and antioxidants to polyethylene's cause deterioration of dielectric properties. Stable cable insertion loss performance in the presence of increasing temperature and frequency makes low loss FEP the right choice for 1 Gbps and beyond SPE Cable.

Fig. 1: Comparison of ethernet materials dissipation factor with increasing frequency.[1]



[1] The impact of dissipation factor on insertion loss at high frequencies above 200MHz is covered in the paper: Designing of Single-Pair Ethernet Cable; Dr. Juliusz Poltz, OptEM Engineering Inc., Canada, 72nd IWCS 2023.

2 Comparison of basic cable performance of SPE insulation materials

Daikin commissioned third party testing of FEP and XLPE insulated SPE prototype cables.

Prototype cables: Single pair, 100ohm, 22AWG (0.35mm^2) prototype.

- Insulated with FEP
- Insulated with XLPE

* Other cable construction details similar and overall cable diameter similar for both.

Test result:

- FEP insulated cable pass at all temperatures and frequencies including both of 100BASA-T1 (66MHz) and 1000BASE-T1 (600MHz) shown in Fig. 2.
- XLPE insulated cables pass at 66MHz for 100BASA-T1 at all temperatures but failure for 1000BASE-T1 at 85°C, 105°C, and 125°C at 200-225MHz shown in Fig. 3.

Fig. 2: Ethernet testing on 15-meter FEP insulated cable.

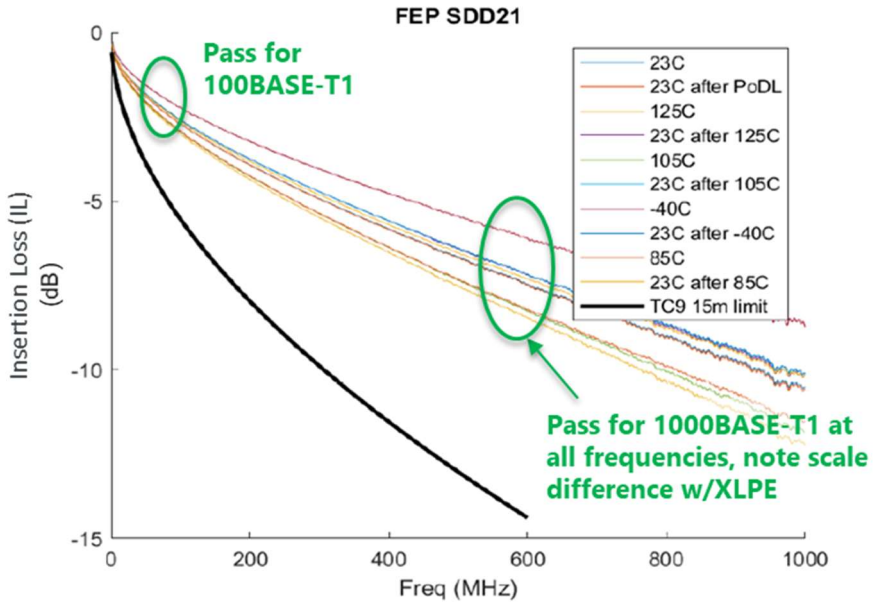
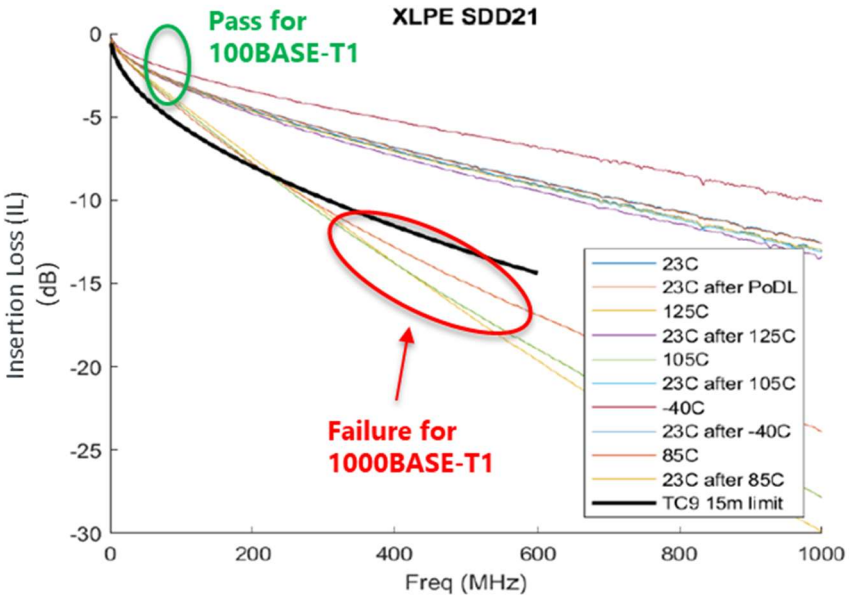


Fig. 3: Ethernet testing on 15-meter XLPE insulated cable.



Due to the sophistication of autonomous driving and the increase in electronic devices, communication cables are required to have faster communication speeds. High speed (2.5 / 5 / 10 Gbps) is expected to be put into practical use in several years, and the electrical characteristics of FEP will be essential to ensure required signal integrity.

As previously discussed, the initial implementation of Level 4 highway pilot systems in the automotive industry is anticipated to become feasible between 2024 and 2025, as depicted in Figure 4, which illustrates the trajectory of autonomous driving technology[2].

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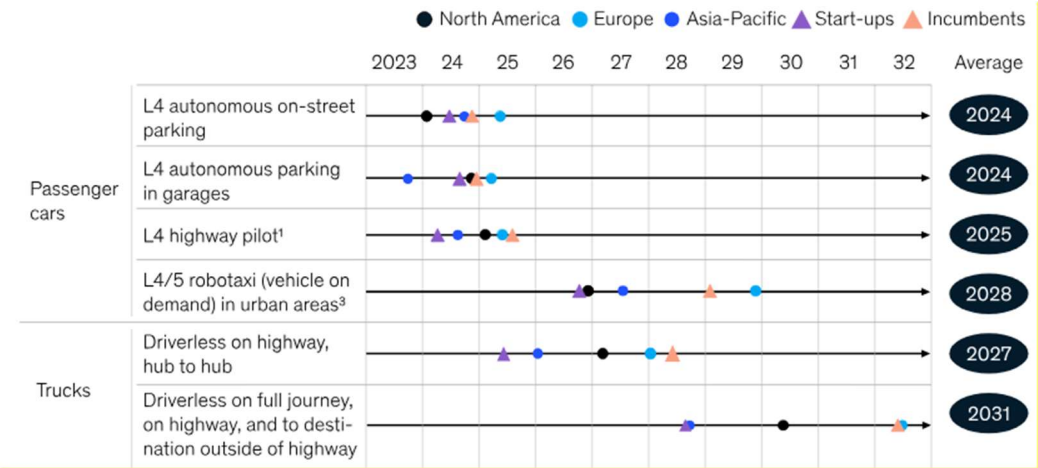
[2] McKinsey & Company surveyed 75 executives from automotive, transportation, and software companies working on autonomous driving worldwide.

https://www.mckinsey.com/features/mckinsey-center-for-future-mobility/our-insights/whats-next-for-autonomous-vehicles#/

Fig. 4: Autonomous driving technology trend.



Level 4 automation represents a significant advancement, featuring heightened automation and increased operational speeds compared to Level 3. Thus, achieving improved data transmission speeds becomes crucial for effective vehicle control at this advanced level. FEP is a vital solution, renowned for maintaining exceptional signal integrity even under challenging conditions, including high temperatures and frequencies. This capability aligns seamlessly with the industry's progression towards more advanced autonomous driving systems. Additionally, in the realms of trucks and agricultural equipment, various original equipment manufacturers (OEMs) have publicly declared their intentions and are actively developing fully autonomous driving systems. This strategic move promises to not only advance these sectors significantly but also alleviate humans from extended and strenuous labour[3,4].

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[3] Volvo Autonomous Solutions and Aurora have achieved the next milestone in their partnership to jointly develop on-highway autonomous trucks in the U.S. A prototype of Volvo Trucks' flagship, long-haul VNL model, integrated with the Aurora Driver technology, was revealed today, representing an important step towards launching fully autonomous Class 8 trucks commercially in North America.
https://www.volvogroup.com/en/news-and-media/news/2021/sep/news-4075850.html

[4] John Deere revealed a fully autonomous tractor that's ready for large-scale production. The machine combines Deere's 8R tractor, TruSet-enabled chisel plow, GPS guidance system, and new advanced technologies. The autonomous tractor will be available to farmers later this year.
https://www.deere.com/en/news/all-news/autonomous-tractor-reveal/

3 Commercial grade SPE cable tests for industry standards

Daikin performed more realistic cable tests on the commercial grade SPE cable design.

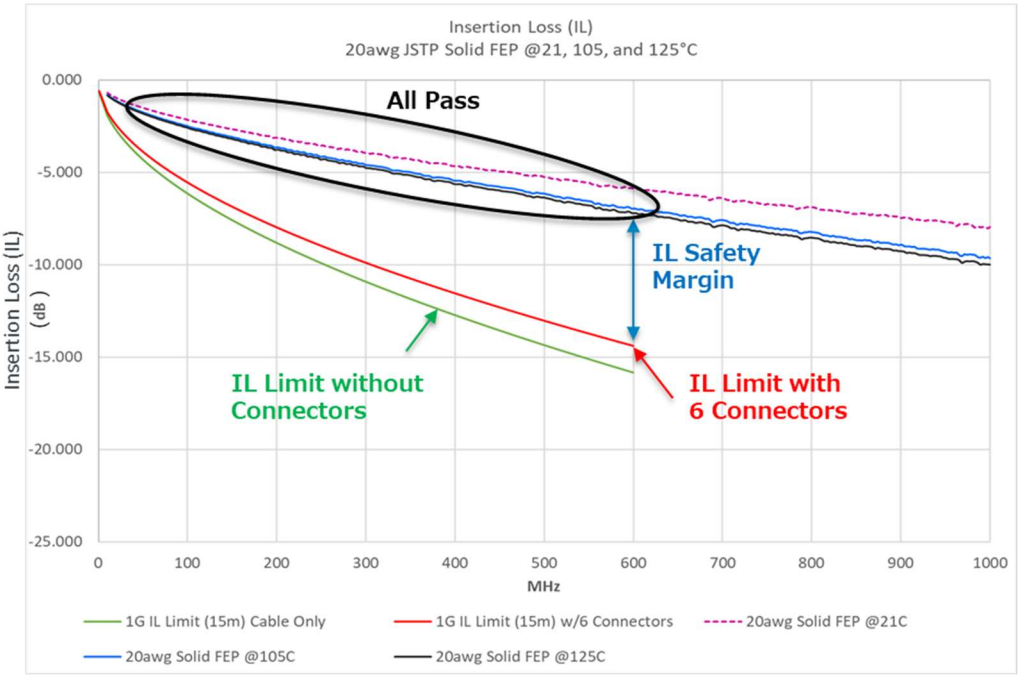
Commercial grade SPE cables:

- 20AWG (0.5mm^2) solid FEP insulated for 1 Gbps - Large commercial vehicle.

20awg solid FEP IL testing for large commercial vehicle 1 Gbps results.

- Limit curves are identical for Open Alliance TC9, and SAE*. SAE also includes a provision for 6 connectors, which tries to simulate an assembled cable.
- The 20AWG solid FEP for large commercial vehicle applications is a very robust construction with plenty of margin. FEP insulated cable passes with significant margin for 20AWG 1000BASE-T1 at all temperatures and frequencies shown in Fig. 5. It easily passes the IL requirements.

Fig. 5: Ethernet testing on 15-meter FEP insulated commercial grade cable.



Industrial standardization for this use is currently underway at SAE and ISO. SAE 1 Gbps, 1000BASE-T1 standard is already published, multi-Gig standard is expected to be complete by end of 2023. ISO 1 Gbps standard is in ballot stage and is expected to be released late 2023. ISO has already begun initiation of beyond 1 Gbps (2.5 / 5 / 10 Gbps) standard. FEP will be only one material to support SAE and ISO standards at all temperatures and/or high speed beyond 1 Gbps. It is unlikely that other materials can meet these standards.

4 Conclusion

As highlighted in the comparative analysis, FEP has demonstrated its exceptional utility when compared to non-PFAS materials such as XLPE, currently used as SPE insulation cables. The unique properties of FEP make it indispensable in ensuring the efficient function of critical infrastructure, especially in the context of future in-vehicle high-speed data requirements to facilitate the advancement of autonomous driving technology. The absence of FEP would pose challenges in achieving the autonomous driving objectives set by industry the establishment of industry standards.

In light of this, we kindly request a no time-limited derogation period (exemption) in the proposed PFAS restriction.

We also understand that practical constrains may necessitate an alternative approach. Hence, should a no time-limited derogation prove unfeasible, we strongly urge the inclusion of an extended derogation period coupled with a review clause. Such an arrangement would allow the cable industry to continue relying on FEP while actively investing in research and development of non-PFAS alternatives. While the possibility of finding a substitute for FEP is slim, it is essential to provide the industry with a practical timeframe to explore potential alternatives. Therefore, we propose a derogation period of no less than 12 years. This duration takes into account the comprehensive process required for the development of new materials. Specifically, it allows for approximately 6 years for material research and development, 2 years for performance validation, and an additional 2 to 4 years for the necessary certifications and full-scale implementation.

Our aim is to ensure that the cable industry can continue fulfilling its role whole upholding the highest standards from technical, economical and safety perspective. By providing this extended derogation period, we can collectively work towards a seamless transition, if and when alternatives to FEP become viable.

In conclusion, we hope that this request will be taken into serious consideration and appropriate measures will be taken.